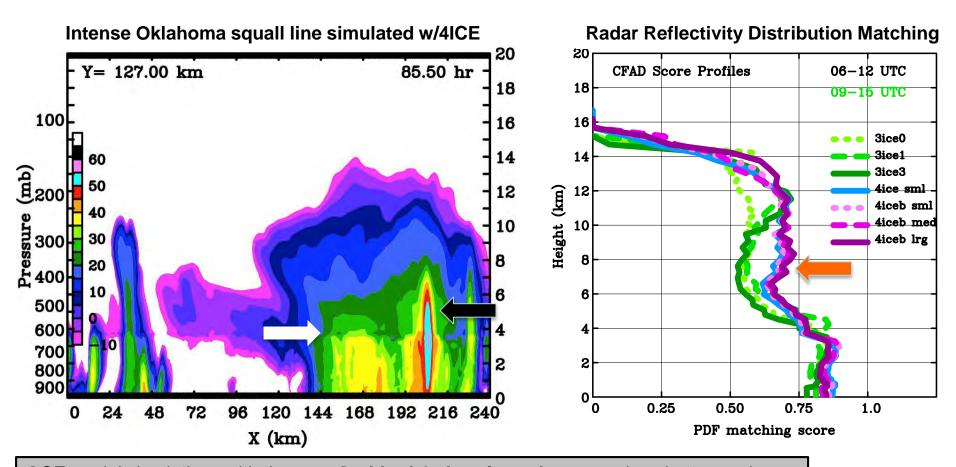# Improving Simulated Radar Signatures in the Goddard Cloud Model

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Intense Oklahoma squall line simulated w/4ICE

Radar Reflectivity Distribution Matching

GCE model simulations with the **new Goddard 4-class ice scheme** produce better peak radar reflectivities and capture both the **erect, intense convective cores** as well as the trailing **horizontally-stratified** region while producing **superior overall echo distributions** in the ice-phase regions of convective systems vs NEXRAD data than earlier 3-ice versions.

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References:

Stephen E. Lang, Wei-Kuo Tao, Jiun-Dar Chern, Di Wu, and Xiaowen Li, 2014: Benefits of a Fourth Ice Class in the Simulated Radar Reflectivities of Convective Systems Using a Bulk Microphysics Scheme. *Journal of the Atmospheric Sciences*, 71, 3583–3612.
doi: http://dx.doi.org/10.1175/JAS-D-13-0330.1

Data Sources: Large-scale forcing data derived from the ARM Southern Great Plains (SGP) sounding network in central Oklahoma and sounding data collected during the TRMM LBA field campaign in Amazonia to force/initialize the Goddard Cumulus Ensemble model (GCE). NEXRAD and S-pol radar reflectivity collected during the MC3E and TRMM LBA field campaigns, respectively, for GCE model validation. We gratefully acknowledge Dr. R. Kakar for his support of GCE modeling studies and development.

Technical Description of Figures:
Simulated radar cross section: Vertical cross section of radar reflectivities simulated using the GCE with the new Goddard 4-class ice (4ICE) scheme with smaller hail for an intense squall line that occurred on 20 May 2011 during the Midlatitude Continental Convective Clouds Experiment (MC3E) in central Oklahoma. The model captures the observed narrow but intense, erect convective cores (shown by the column of dBZ > 50 in pink and blue) as well as the broad area of weak, horizontally stratified echoes in the trailing stratiform region. Earlier versions of the parameterized GCE cloud physics relied on 3-classes of ice (small cloud ice, snow, and graupel or hail) to simulate convective systems, making it difficult to simulate systems of varying intensity and location without choosing the third ice class *a priori*. The new 4ICE scheme has both graupel and hail and can respond appropriately to the full range of atmospheric instability, generating large amounts of hail in convective cores in response to strong updrafts in highly unstable conditions as well as little or no hail in weaker updrafts associated with stable conditions. "4iceb" includes a rain evaporation correction.
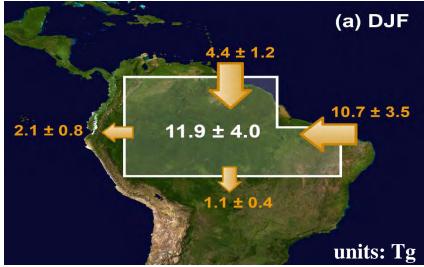*Profiles of distribution agreement:* CFADs (contoured frequency with altitude diagrams) show PDFs of a given field at each vertical level, which are then contoured. The degree of overlap (1=perfect; 0=none) between PDFs of the observed and simulated radar reflectivity distributions at each vertical level show how well the overall distributions agree with one another as a function of height. Here CFAD scores show that the new 4ICE scheme produces total (convective + stratiform + anvil) reflectivity distributions that agree better with the NEXRAD observed than 3ICE distributions above the freezing level.

Scientific significance, societal relevance, and relationships to future missions: Cloud-resolving models (CRMs), such as the GCE, are critical to both the study and representation of cloud systems and their precipitation processes. Not only have CRMs promoted our understanding of precipitation processes and their interactions with land, ocean, and radiation, but their synthetic cloud data can serve as a crucial proxy for real cloud processes, including those hard to measure (e.g., cloud heating components). The GCE has and continues to be used to provide 4D cloud datasets from numerous environments for the development of TRMM and now GPM precipitation and cloud heating algorithms. The accuracy of those algorithms depends in part on how well the cloud data from the GCE capture true cloud systems. The new 4ICE scheme significantly improves the quality of those cloud data for a variety of environments. Furthermore, with advancing computing power, physics packages developed for CRMs can now be used in meso- and global scale models. Such is the case with the new 4ICE scheme, which has now been implemented into the NASA Unified WRF and Goddard MMF models.
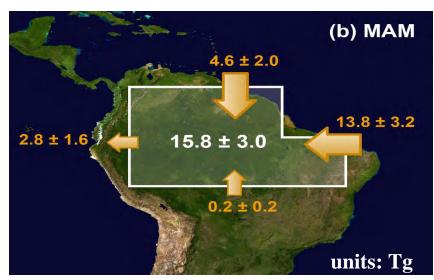
Earth Sciences Division - Atmospheres

Saharan Dust Prevents Phosphorus Depletion in the Amazon Rainforest

Hongbin Yu, *Code 613, NASA/GSFC and ESSIC/University of Maryland*

(a) DJF — units: Tg

(b) MAM — units: Tg

- CALIPSO lidar characterizes the dust transport across the Atlantic Ocean in three dimensions (top left).

- 27.7 Tg or million tons of dust is deposited in the Amazon rainforest annually (sum of white numbers in right panels), according to 2007 - 2013 CALIPSO record.

- The Saharan dust feeds the Amazon rainforest yearly with an estimated 22,000 tons of phosphorus, replenishing the leak of plant-essential nutrient by rains and flooding.

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References:

Yu, H., M. Chin, T. Yuan, H. Bian, L. A. Remer, J. M. Prospero, A. Omar, D. M. Winker, Y. Yang, Y. Zhang, Z. Zhang, and C. Zhao, The fertilizing role of African dust in the Amazon rainforest: A first multiyear assessment based on data from Cloud Aerosol Lidar and Infrared Pathfinder Satellite Observations, *Geophysical Research Letters, 42,* doi:10.1002/2015gl063040, 2015.

Technical Description of Figures:
Left Panel: CALIOP observations reveal the three dimensional characteristics of a dust event (March 26-April 2, 2010). Curtains show profiles of dust extinction coefficient (km^{-1}). Dust was distinguished from other types of aerosol using the CALIOP-observed particulate depolarization ratio. An ensemble of 7-day back trajectories starting from Barbados (B) and Cayenne (C) respectively, is overlaid over the curtains.
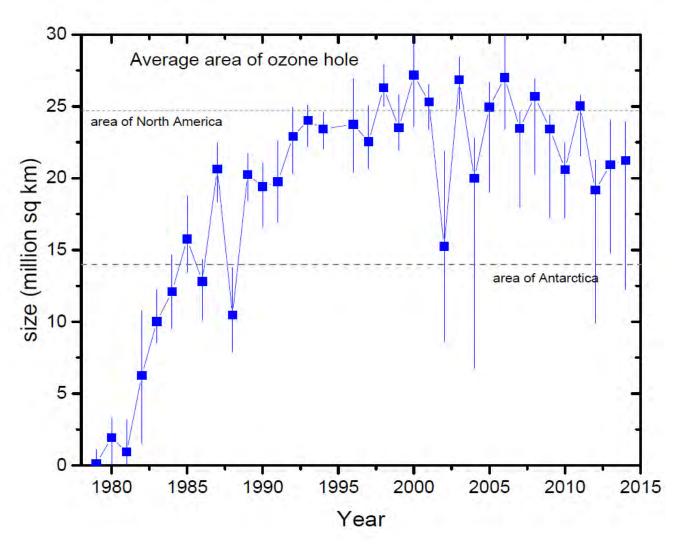
Right Panels: CALIOP estimated seasonal (left in DJF and right in MAM) dust mass fluxes (orange color, mean ± 1σ, σ represents the standard deviation over the 7 years) across the boundaries of the Amazon Basin (white lines) and the estimated dust deposition (white color) in the Basin. All numbers have units of Tg (equivalent to million tons). CALIOP aerosol profiles in both cloud-free and cloudy conditions were used. The yearly deposition of 27.7 Tg of Saharan dust is estimated to supply 22,000 tons of phosphorus (comparable to the loss by rain and flooding) to the Amazon rainforest, a climate-essential ecosystem whose productivity is limited by the deficiency of phosphorus in Amazonian soil.

Scientific significance, societal relevance, and relationships to future missions: Dust cycle has become an emerging core theme of Earth system science. This study provides the first observation-based multiyear estimate of dust deposition in the Amazon basin based on the CALIPSO all-sky aerosol measurements. The data can be used to evaluate and constrain highly uncertain model simulations. The analysis suggests that the phosphorus input associated with the dust can effectively replace phosphorus depletion by rains and flooding from the Amazon basin. Recently launched DSCOVR and CATS missions will continue to monitor such dust transports with enhanced capabilities. A future Aerosol-Cloud-Ecosystem (ACE) mission would provide more accurate measurements of aerosol three-dimensional distributions and particle properties, which would further improve our ability to assess the implications of dust on the Earth's biosphere through large-scale transport.

Earth Sciences Division - Atmospheres

Is the Antarctic Ozone Hole Beginning to Recover?

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The ozone hole is defined as the area for which ozone is less than 220 Dobson units. Now that CFCs and other ozone depleting chemicals have been controlled, it is predicted that full recovery of ozone to pre-1979 levels should occur by about 2050. Aura OMI and NPP OMPS will track the ozone recovery.

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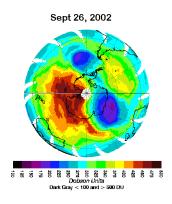E-mail: richard.d.mcpeters@nasa.gov
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References:

McPeters, R.D., M. Kroon, G. Labow, E. Brinksma, D. Balis, I. Petropavlovskikh, J. Veefkind, P.K. Bhartia, and P. Levelt, Validation of the Aura Ozone Monitoring Instrument total column ozone product, J. Geophys. Res., 113, D15S14, doi:10.1029/2007JD008802, 2008.

Data Sources: The ozone data used to compute ozone hole area was from the Total Ozone Mapping Spectrometer (TOMS) on Nimbus 7 (1979-1992), from the TOMS instrument on Meteor 3 (1993 and 1994), from Earth Probe TOMS (1996-2004) and from the Ozone Monitoring Instrument (OMI) on Aura (2005-2014). The data were processed using the version 8 ozone algorithm, except for OMI which used the version 8.5 algorithm that takes advantage of OMI's hyperspectral sensor.

Technical Description of Figure:

The ozone in the Antarctic has been mapped by Nimbus TOMS, Earth Probe TOMS, OMI on Aura, and now OMPS on NPP. The area over which ozone is less than the 220 Dobson Unit threshold is mapped each day. The 30 day average area is plotted for each year from 1979 to the present. The vertical bars show the range of minimum to maximum daily area over the averaging period. Notice that the ozone hole in 2002 was anomalous when the meteorology of the Antarctic that year led to a very early breakup of the ozone hole (see image at right).

Sept 26, 2002

Dobson Units
Dark Gray < 100 and > 500 DU

Scientific significance and societal relevance:

Ozone observations are important because ozone is the critical absorber of ultraviolet radiation and because it affects climate. The abundance of ozone directly affects the Earth's biosphere since the total column amount of ozone overhead determines the amount of ultraviolet light that reaches the ground. The decline in ozone resulting from the release of CFCs, particularly the development of the Antarctic ozone hole each year, has been a clear example of man's effect on the global environment. An accurate time series of total column ozone is needed to document the changes that have occurred in ozone. A continuing time series is needed to verify the expected recovery of ozone as a result of the Montreal Protocol.